H. SEEGER[1]

The history of German waste water treatment

This paper describes the development of municipal waste water treatment technology in Germany in the 20th century. It is based on a systematic study of the main technical journals in Germany dealing with waste water treatment: GWF - Wasser/Abwasser, Gesundheitsingenieur (Ges-Ing) for the period until 1950, and Korrespondenz Abwasser (KA) for the period after the war. The main stages of the development are presented in flow-charts showing sewage plants typical of the time indicated. Some political and economic factors affecting the technical development are also considered.

INTRODUCTION

Today the treatment of domestic and industrial waste water is a matter of course in our society. It serves the protection of human health, the preservation of water as an ecosystem, and it also retains the water in a state that makes it usable by humans. However, the accomplishing of this task was not always taken for granted or even seen as necessary. In Germany, the development of the waste water treatment technology to the state we have today began more than a hundred years ago. During this time the aims have changed as much as the technical means to realise them.

As in other nations, in Germany the increased importance attached to the subject of waste water was connected to the rapid industrialisation and urbanisation during the second half of the 19th century. There was a steep rise in the urban population, as is shown in Table 1, and new conurbations came into being. There were several epidemics in the cities, causing numerous deaths. Two vital waterborne diseases in this period were typhoid and cholera. Cholera only occasionally occurred and in limited areas, in 1831 for the first time in Germany. In 1866/67, a massive wave of cholera epidemics spread over the whole of Germany. Typhoid, on the other hand, had a permanent presence in the cities, and it continued to show high mortality rates up to the late 19th century.

Slowly the idea was accepted that the cause of the epidemics had to be looked for in the cities' bad sanitary conditions. The studies done by Von Pettenkofer, who was Ordinarius for sanitation in Munich 1866 - 1894, contributed in particular to the acceptance of this idea. One of the main prerequisites for improving the sanitation of the cities was the efficient removal of the numerous kinds of waste water. Although street-draining facilities existed in most cities, they were not designed to handle the high quantities of waste water produced in the densely populated cities of the late 19th century. Thus the construction of sewer systems became necessary.

Table 1. The rise in population of German cities in the second half of the 19th century [1]

City	Population 1852	1900
Berlin	450,000	1.75 Mill.
Hamburg	180,000	650,000
München	105,000	500,000
Leipzig	70,000	455,000
Breslau	120,000	425,000
Frankfurt	65,000	285,000
Stuttgart	50,000	180,000
Essen	10,000	130,000

Although a sewer system had been constructed as early as 1842 in Hamburg, the general introduction of sewers in the German cities started with the construction of a system in Frankfurt/ Main in 1867, just after the biggest wave of cholera epidemics. Table 2 shows the construction dates of the first German sewer systems.

Table 2. Sewer construction in German cities

City	Construction date
Hamburg	1842
Frankfurt	1867
Stettin	1868
Danzig	1871
Berlin	1873
Breslau	1877
München	1881
Köln	1881
Düsseldorf	1884

The discharge of large quantities of urban waste water into the recipients via centralised sewer networks eventually caused considerable pollution of the rivers, resulting in a need for waste water treatment [2].

THE FIRST PERIOD: UNTIL THE FIRST WORLD WAR

Wastewater treatment began with the improvement of the hygienic state of urban water bodies. Its aim was the purification of polluted water to a degree that it would no longer be harmful to humans. A description of this intent is given in a decree issued in 1888: "The permissible degree of pollution is to be measured in a way that unmistakable signs

[1]Universität Gesamthochschule Kassel, FB 14, FG Abfalltechnik, Mönchebergstrasse 7, D-34109 Kassel, Germany. E-mail hseeger@hrz.uni-kassel.de

[1]The title means that he was acting as the chief adviser of the city government in all questions regarding public health and city sanitation.

Table 3. Examples of early municipal sewage plants

Community	Opening date	Methods
Danzig	1871	sewage fields
Berlin	1873	sewage fields
Frankfurt/Main	1887	grit removal, screens, settling tank
Freiburg	around 1890	sewage fields
Darmstadt	around 1890	sewage fields
Leipzig	1894	chemical precipitation
Marburg	1897	grit removal, screens, settling tank
Düsseldorf	1902	screens, settling tank
Mönchengladbach	1902	settling tank
Mannheim	1903/05	grit removal, screens, settling tank
Frankfurt/Oder	1905	screens, strainer
Wuppertal	1906	grit removal, screens, settling tank
Straßburg (pilot plant)	1907/11	coarse screen, straining wheel, settling tank, oxidation ponds
Essen – Nordwest	1908	Imhoff Tank
Herne (3)	1909, 1910, 1921	Imhoff Tank
Duisburg – Kaßlerfeld	1909	screens, grit removal, oil separator, straining disc
Dresden	1910	straining disc
Wiesbaden	1910	grit removal, screens, settling tank
Krefeld	1910	grit removal, screens
Hanau	1910	grit removal, screens
Essen – Recklinghausen	1912	screens, grit removal, oil separator, settling tank
Karlsruhe	1913	straining wheel, sieving disc
Mainz	1913/14	screens, settling tank, sieving disc
Hildesheim	1914/15	grit removal, screens, trickling filter
Duisburg	1915	Imhoff Tank
Stuttgart	1916	Imhoff Tank, trickling filter
Ludwigshafen	1923	grit removal, screens, sieving disc
Heidelberg	1924	grit removal, screens, sieving disc
München	1925	grit removal, screens, settling tank, oxidation ponds

of stinking rottenness have to be absent even at the lowest level of the river water and the highest heat of summer" [2].

The first waste water treatment was the natural treatment on irrigation fields. However, soon artificial treatment in sewage plants became common. The first such plant in Germany was constructed in Frankfurt/ Main in 1887. Table 3 shows the first municipal sewage plants.

In the beginning, mechanical facilities such as screens, grit removal, strainers, and settling tanks were used. The knowledge of these technologies was adopted from England, as in the case of sewer constructions. The flow-chart presented in Figure 1 shows a typical plant of that time.

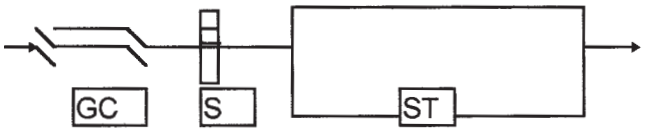


Figure 1. A typical sewage plant around 1890: grit chamber (GC), screen (S), settling (ST)

However, the German development of waste water treatment soon took its own course, owing in part to the different geographical conditions in Germany with generally larger recipients. Nevertheless, the influence of experiences from abroad remained an important factor.

Further development of the methods of mechanical treatment was the main goal of German waste water treatment research until the First World War. Methods of settling received most attention and were seen in Germany as the main stage of sewage plant development until the end of the Second World War.

Where supplemental biological treatment was considered necessary, this was done by trickling the waste water on irrigation fields set aside for that purpose. As mentioned above, the first irrigation fields were used for waste water treatment before it became common to rely on artificial treatment (i.e. settling tanks) in sewage plants. Around the turn of the century, trickling filters were introduced as the first artificial biological treatment method as well. Compared with the irrigation fields they were characterised by a much lower need of space and lower

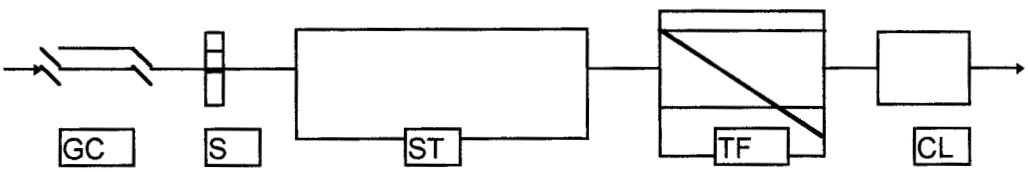


Figure 2. A typical sewage plant after the introduction of trickling filters (TF).The TF is followed by an additional settling process, clarification (CL).

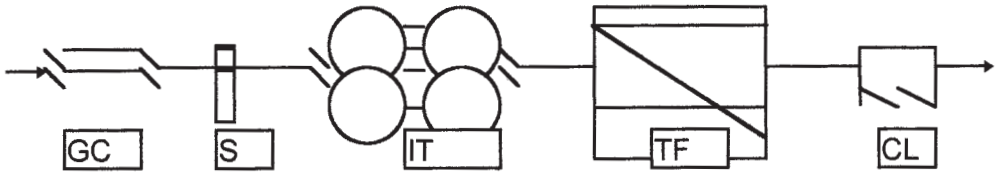


Figure 3. An Imhoff Tank (IT) plant around 1910.

operation costs, and they soon became widespread. A typical sewage plant then followed the principle shown in Figure 2. An additional method of supplemental biological treatment, developed in Germany, were oxidation ponds. They were first introduced in Berlin in 1898 in combination with the local irrigation fields.

One problem connected with the settling methods right from the beginning was the handling of the resulting sludge. The solution to this problem was the Imhoff Tank, patented in 1906, which consisted of a cylindrical settling tank and a digestion tank directly underneath. The Imhoff Tank, being the model for other so-called two-storied facilities, introduced anaerobic sludge digestion as the most commonly used method of sludge treatment in Germany. In the process of sludge treatment, digestion was followed by dewatering on drying beds and transportation for agricultural purposes. A typical sewage plant using the Imhoff Tank is presented in Figure 3, the first one of this kind having been taken into operation in Essen in 1908 [3, 4].

THE SECOND PERIOD: UNTIL THE RULE OF THE NATIONAL SOCIALISTS

The First World War led to the first interruption in the installation of waste water treatment facilities. The introduction of waste water treatment had until this time not yet reached a state where the basic demands of treatment were being fulfilled in all parts of Germany. Economic problems after the end of the war prevented the construction of new sewage plants and increased the deficit. Nevertheless, the technology of waste water treatment had been developed further. By the mid-1920s, the crisis had been overcome, and innovations began to be implemented [4]. Foremost among these was the activated sludge process as a new artificial biological method, which was employed first in Germany in the sewage plant of Essen-Recklinghausen in 1925. Compared with trickling filters, it offered a higher standard of treatment. An additional advantage was that with this method stench and flies no longer posed a major problem, and it became possible to operate sewage plants within city boundaries. However, activated sludge facilities required high investment costs and needed a high level of maintenance, and this slowed down the adoption of the activated sludge process [5].

Another innovation, introduced in Leipzig in 1927, was the development of automatic sludge scraping systems for the shallow settling tanks that now began to displace the two-storied systems [6]. This was accompanied by sludge digestion being carried out in separate digestion tanks. To significantly improve the digestion, these digestion tanks were equipped with stirring and heating systems. The interest in sludge digestion ran high because of the utilisation of the gas produced by the digestion process as fuel; the first use of digestion gas in this way was made in Essen - Recklinghausen in 1924 [7]. Sludge digestion in special digestion tanks became the standard for the larger urban sewage plants. Such a plant is shown in Figure 4.

Besides these developments in the field of urban waste water treatment, the treatment of industrial waste water also received more attention. Chemical-physical methods were developed to an increased extent for those industrial waste waters that mechanical and biological methods had failed to treat effectively [8].

In 1931 the Great Depression began to be severely felt in Germany and the period of high activity in the field of waste water treatment ended. However, at that moment, an effort was launched to increase standardisation in the field of waste water treatment, and the creation of a uniform German water law became a major goal [9].

THE PERIOD OF NATIONAL SOCIALIST RULE

National Socialistic rule brought with it a change in the practice of waste water treatment. Now the priority in the field of waste water treatment was given to agricultural utilisation in the form of widespread irrigation of waste water. This was based on the Blood and Soil ideology of the National Socialists, in which the farmer was cherished as the backbone of a strong and healthy society. In addition, the expected increase in food production was also connected with

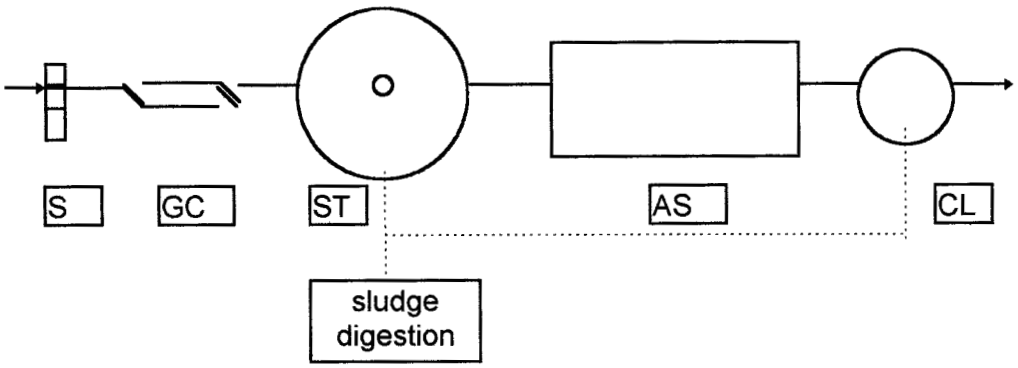


Figure 4. An activated sludge (AS) plant around 1930.

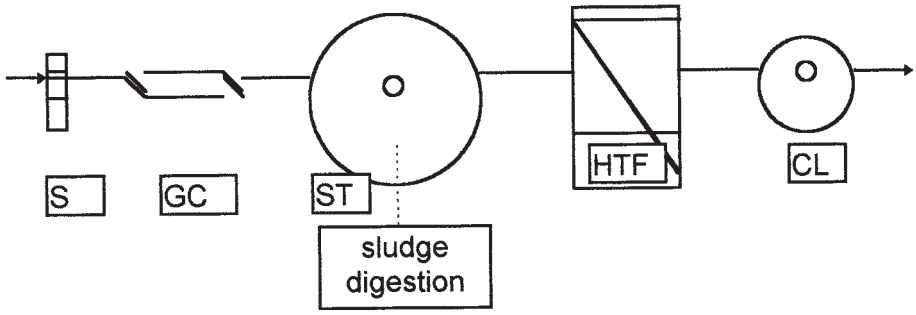


Figure 5. A typical sewage plant using a high-loaded trickling filter (HTF).

the struggle for self-sufficiency. The development of the conventional waste water treatment technology also continued, and in this period a high-loaded trickling filter was introduced into some sewage plants [10]. A flow-chart of a sewage plant employing the high-loaded trickling filter is presented in Figure 5.

Altogether, the competition between the two rival ways of waste water disposal led to low activity in the field. That a large part of Germany's economic power went into rearmament also played a role. The Second World War then led to a nearly complete standstill of all activity in the field of waste water treatment, and in addition many sewage plants were not spared from being damaged during the war [11].

THE POST-WAR PERIOD

After the end of the Second World War, a large deficit in waste water treatment existed in Germany. Already at that time, before water pollution became a big public issue, experts understood the critical condition of the waters, and increasing demands on the quality of treatment in the sewage plants were made. Full biological treatment became the general aim for urban waste water treatment, and the high-loaded activated sludge process was introduced in Germany in the 1950s. The first German sewage plant employing this process was completed in 1952 in Wuppertal. The activated sludge process then became the dominant method of treatment in Germany [12-14]. A flow-chart of this type of sewage plant is shown in Figure 6.

At this time, the nutrients nitrogen and phosphorus attracted attention. The prevention of eutrophication became a new goal for waste water treatment in general, however a tertiary treatment was not yet felt to be necessary. One reason for this must have been the unavailability of efficient methods of treatment. However, the development of a nutrient removal method was initiated.

Water pollution continued to get worse. The waste water treatment plants were not able to cope with the increasing population and the expanding economy, flourishing since the mid-1950s [15, 16]. Generally speaking, the peak of water pollution in West Germany was reached in the late 1960s.

THE MODERN PERIOD SINCE 1960

A national Water Act in 1960 provided the first common framework for water protection in Germany. From then on, continuous efforts for increased waste water treatment led gradually to a notable improvement in water quality.

However, the extension of urban waste water treatment brought the return of the sludge problem, which was thought to have been solved at the beginning of this century. The huge amounts of sludge forced the abandonment of the dewatering of the digested sludge on drying beds. This method was discontinuated due to a lack of space and artificial dewatering methods employing filter presses and centrifuges were added to the sewage plants. Consequently, the typical set up of a plant became similar to the one presented in Figure 7. Because the disposal of all sludge by agricultural means was no longer possible, the problem was partially remedied by the dumping it on landfills.

Increasing consciousness of environmental protection among the population since the late 1960s led to further governmental measures for water protection. In 1979 the First General Regulations Concerning the Discharge of Municipal Wastewater issued target values for the parameters BOD_5 and COD. The overall aim of waste water treatment had changed from the protection of human health to the protection of the environment and water as an ecosystem.

Dumping of sludge increased notably in the beginning of the 1970s, as the purchase of sludge for agricultural use decreased when it became known that it was substantially polluted by heavy metals and organic toxic substances. At the end of the 1980s, bottlenecks for dumping appeared and sludge incineration became more important. In all, the sludge

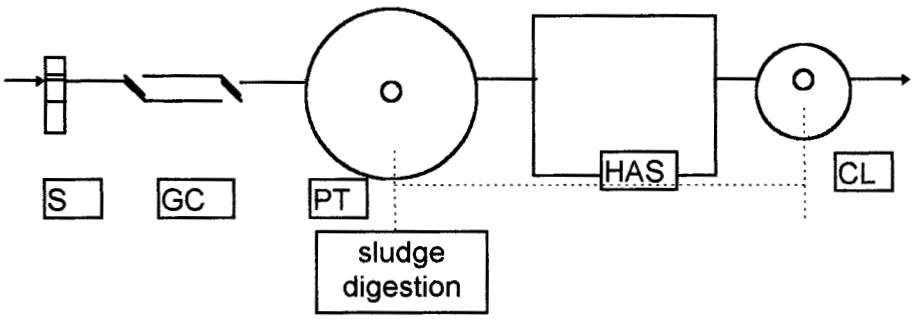


Figure 6. A typical sewage plant employing the high-loaded activated sludge (HAS) process after pre-treatment (PT), introduced around 1955.

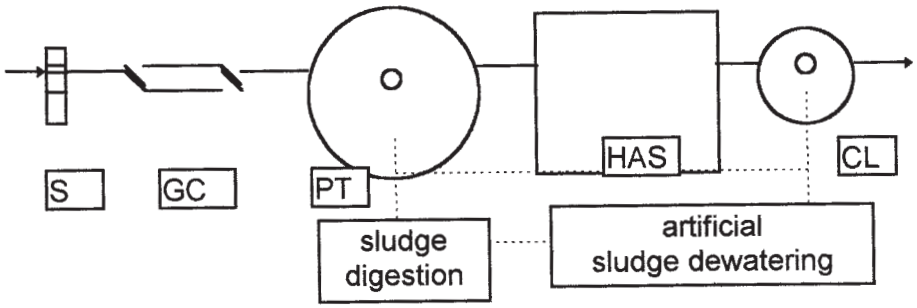


Figure 7. The introduction of artificial sludge dewatering around 1970.

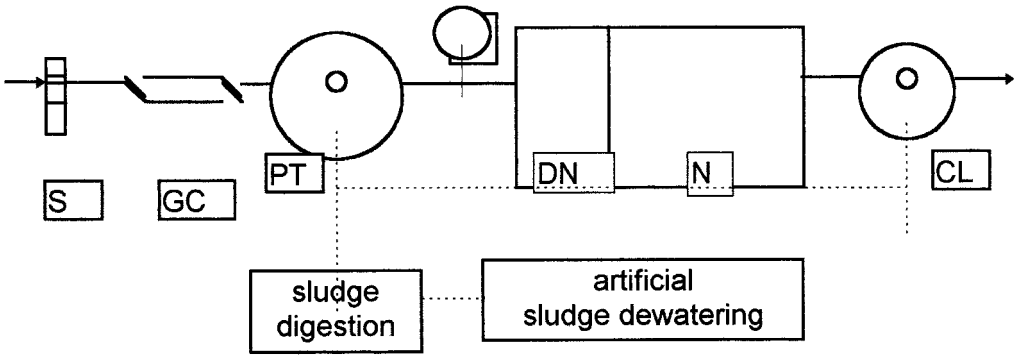


Figure 8. A typical sewage plant including nutrient removal.

problem became, and still is, one of the most important subjects in the field of waste water treatment [17].

In the 1980s the methods for tertiary waste water treatment were developed to a degree which made their practical application possible, the first municipal sewage plant with denitrification already having been taken into operation in Biet in 1978 [18]. A statutory requirement for tertiary waste water treatment emerged in 1989 with the amendment of the First General Regulations Concerning the Discharge of Municipal Wastewater, which also issued target values on nitrogen and phosphorus. Thereafter the sewage plants were re-equipped according to the principle shown in Figure 8 to meet the new demands. Finally, waste water treatment technology allowed nearly complete treatment. The decision about the degree of treatment was by now no longer limited by the technology available, but mainly by the amount of money and political will.

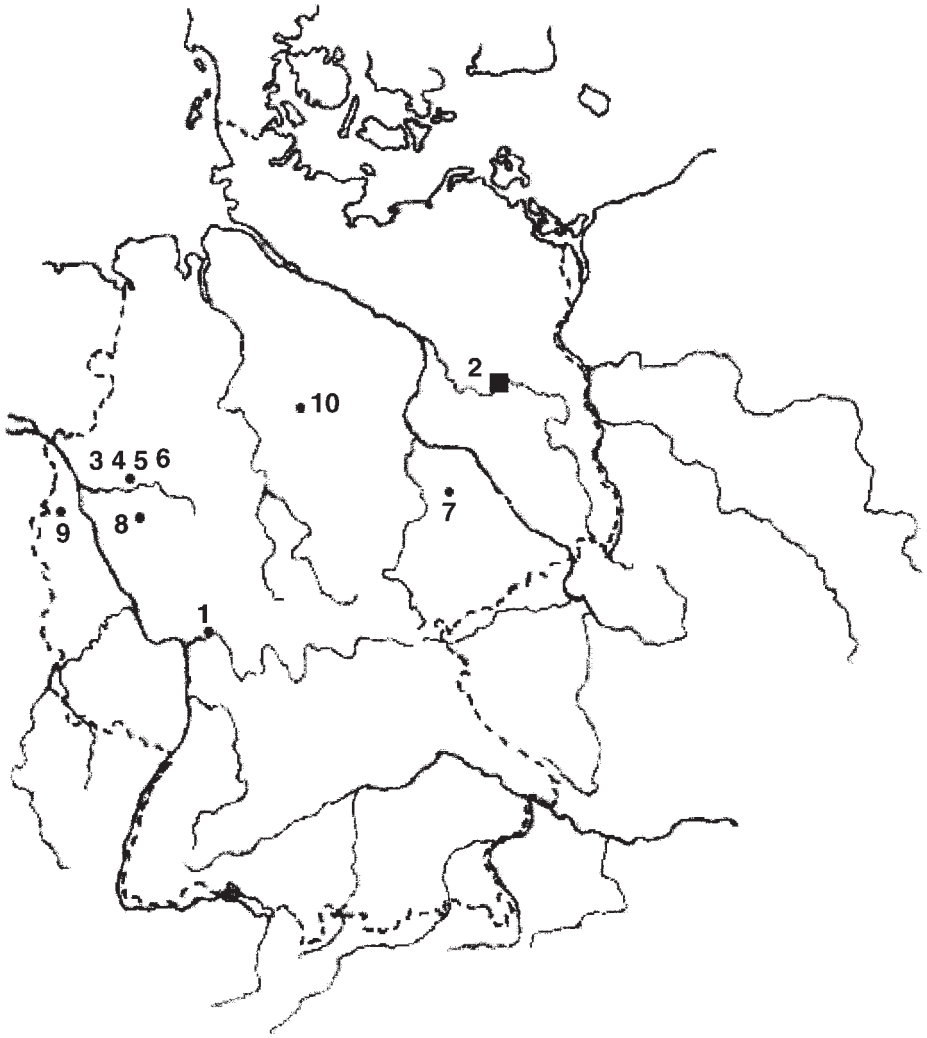
CONCLUSIONS

The development of the waste water treatment technology in Germany can be seen as a steady process. It started in the late 19th century with irrigation fields as the first method of biological treatment and mechanical treatment for the first sewage plants. Already before the First World War, artificial biological treatment with trickling filters was introduced and the Imhoff Tank introduced sludge digestion. The period between the two world wars saw improvements in all fields of waste water treatment technologies. Automatic sludge scraping systems simplified sludge removal compared to the mechanical treatment, the activated sludge process was introduced as an improvement method of artificial biological treatment, and, for better sludge digestion, special digestion tanks with heating and stirring systems were developed. Then, shortly before the Second World War, the trickling filters were replaced by the more efficient high-loaded trickling filters. After the Second World War, the same occurred with the activated sludge process, and the high-loaded activated sludge process has now become the basic method of waste water treatment. The final two major steps towards the current state of waste water treatment were the introduction of artificial sludge dewatering during the 1960s, and the addition of nitrogen and phosphorus removal to all municipal sewage plants after the issuance of new target values for waste water in 1989.

However, this development process was certainly not continuous. Political and economic events had an impact, even stopping the development process almost completely for some periods of time. In the first case the First World War and the following economic crisis brought an interruption of about ten years. On the second occasion, it was the economic crisis of the 1930s, which was followed by the National Socialist rule and another war. This interruption lasted about fifteen years.

The technology itself did not follow just one, but several parallel lines of development. Often, outdated methods of treatment were taken up again. One example can be seen in settling tanks, first constructed in rectangular shape, then replaced by deeper circular types like the Imhoff Tank, before the invention of automatic sludge scrapers led to shallow rectangular tanks often being used again. Another example is natural biological treatment. In the form of irrigation fields, it was the first kind of waste water treatment. However, it was replaced by artificial treatment in sewage plants. During National Socialist rule it was revived for a short time as agricultural waste water utilisation. And now small scale biological treatment is of interest again in connection with ecological housing and decentralised waste water treatment.

The technology has developed steadily to meet the demands of waste water treatment. However, during the development process, the assumptions on which the treatment methods were based and selected often changed, and abandoned technologies, often in modified and improved form, reappeared.



1 In 1887, in Frankfurt construction of the first sewage plant in Germany
2 First oxidation ponds in 1898 in Berlin
3 Foundation of the Emschergenossenschaft as the first self-administered waste water cooperative in 1904
4 In 1906, development of the Imhoff Tank
5 First utilisation of digestion gas at the sewage plant of Essen-Recklinghausen in 1924
6 First use of the activated sludge process in Germany at Essen-Recklinghausen in 1925
7 In 1927, in Leipzig development of an automatic sludge scraping system
8 Introduction of the high-loaded activated sludge process in 1952 in Wuppertal
9 Development of artificial sludge dewatering at the Niersverband in the late 1950's
10 Begin of biological phosphorus elimination in Hildesheim in 1986

Figure 9. The locations of the major developments in the German waste water treatment technology.

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